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Intyg
Certificate

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För Patent- och registreringsverket
For the Patent- and Registration Office

Lina Oljeqvist

Lina Oljeqvist

Avgift
Fee

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COMPOSITE AMPLIFIER

TECHNICAL FIELD

The present invention relates to a composite amplifier, a transmitter including such an amplifier and a method of driving a composite amplifier.

BACKGROUND

In many wireless communications systems, the power amplifiers in the transmitter are required to be very linear, in addition to being able to simultaneously amplify many radio channels (frequencies) spread across a wide bandwidth. They also have to do this efficiently, in order to reduce power consumption, need for cooling and to increase the lifetime of the amplifiers. The linearity is required to be good since nonlinear amplifiers would cause leakage of interfering signal energy between channels.

The amplitude probability density of a mix of sufficiently many independent radio frequency (RF) channels, or of a multi-user CDMA signal (CDMA = Code Division Multiple Access), tends to be close to a Rayleigh distribution having a large peak-to-average power ratio. In order not to compress the waveform, the amplifier must be operated with the average power backed off from the peak power of the amplifier. Since a conventional RF power amplifier (especially class B) generally has an efficiency proportional to its output amplitude, its average efficiency is very low for such signals.

In response to the low efficiency of conventional linear power amplifiers, several methods have been proposed. One of these is the Chireix outphasing method [1], sometimes and in some embodiments called "linear amplification using nonlinear components" (LINC). These methods have so far been unsuccessful in delivering the theoretical high efficiency for high peak-to-

average ratios and wide bandwidths, especially while maintaining high linearity and when using practical RF transistors.

Another attempt to increase efficiency in an amplifier system is described in [2, 3]. However, this system has the drawback that it requires at least 3 power amplifiers.

SUMMARY

An object of the present invention is to improve the efficiency of composite amplifiers including two power amplifiers connected to a Chireix type output network.

This object is achieved in accordance with the attached claims.

In one embodiment the present invention drives the power amplifiers forming the composite amplifier in two modes, namely a Chireix type outphasing mode above a transition point and a linear mode below the transition point.

In another embodiment the present invention drives the power amplifiers in a mode combining linear and nonlinear drive signals above the transition point and a linear mode below the transition point.

The composite amplifier in accordance with the present invention requires only two power amplifiers, which has several advantages. The composite amplifier will be easier to design and build, and only two drive signals have to be generated. The last point is especially important when using adaptive techniques (such as digital pre-distortion), since there are fewer adjustments.

In addition to increasing the efficiency, the solution in accordance with the present invention also increases the usable bandwidth and improves linearity.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

Fig. 1 is a block diagram of a prior art Chireix amplifier;

Fig. 2 is a diagram illustrating drain efficiency versus normalized output voltage for a conventional Chireix amplifier;

Fig. 3 is a diagram comparing transistor current versus normalized output voltage for a conventional Chireix amplifier and a composite amplifier in accordance with the present invention;

Fig. 4 is a diagram similar to Fig. 2 comparing the efficiency of a conventional Chireix amplifier to the efficiency of a composite amplifier in accordance with the present invention;

Fig. 5 is a diagram illustrating the complex normalized transistor currents of a conventional Chireix amplifier and of a composite amplifier in accordance with the present invention;

Fig. 6 is a block diagram of an exemplary embodiment of a composite amplifier in accordance with the present invention;

Fig. 7 is a block diagram of another exemplary embodiment of a composite amplifier in accordance with the present invention;

Fig. 8 is a flow chart illustrating an embodiment of the method in accordance with the present invention; and

Fig. 9 is a diagram comparing the drive signal spectrum of the present invention to the drive signal spectrum of the prior art.

DETAILED DESCRIPTION

In the following description the same reference designations will be used for the same or similar elements throughout the figures of the drawings.

Furthermore, although they are not identical, the output networks of both Chireix and LINC amplifiers will be denoted Chireix type output network or combiner.

Fig. 1 is a block diagram of a conventional Chireix amplifier. The term "outphasing", which is the key method in Chireix and LINC amplifiers, generally means the method of obtaining amplitude modulation by combining two phase-modulated constant-amplitude signals produced in a signal component separator 10. After up-conversion and amplification through RF chains 12, 14 (mixers, filters, amplifiers) and power amplifiers 16, 18, the outphased signals are combined to form an amplified linear signal in a Chireix type output combiner 20. The phases of these constant-amplitude outphased signals are chosen so that the result from their vector-summation yields the desired amplitude. All amplitudes from zero to full amplitude, as well as negative amplitudes, can be obtained in this way.
The theoretical efficiency of outphasing amplifiers with Chireix type output combiners has been derived in [4, 5]. The assumption in [4] is that the two constituent amplifiers (i.e. transistors or parallel combinations of transistors) are working as class-B or class-C amplifiers in saturation. This makes them act as constant RF voltage sources, and the peak efficiency is assumed to be the same as for class-B amplifiers. In [5], the assumed peak efficiency is 100%. In addition to deriving efficiency calculations for constant-voltage-source Chireix amplifiers, reference [5] also states that a similar theoretical analysis can be performed assuming constant-current RF sources.

A major problem with present Chireix and LINC amplifiers is the poor efficiency at low amplitude levels, as illustrated in Fig. 2. At very low levels the efficiency is even worse than for an ordinary class B amplifier. The reason for this is that the power amplifier transistors deliver more RF current than necessary (this can be seen in Fig. 3). This RF current is mainly out of phase with the transistor RF voltage, which means that little or no RF power is generated (the DC power, however is mainly proportional to the RF current).

In a conventional Chireix amplifier, where the transistors are saturated, the drive power at low output levels is the same as at high output levels. In order to keep the transistors saturated, the drive power has to be substantially larger than for a class B amplifier. When the peak-to-average ratio of the signal is high, the average output power has to be backed off, but the average drive power stays the same. In severe cases the average drive power can even be as large as the average output power.

A problem associated with high drive signal levels at low output signal levels is the phase discontinuity at zero crossings. This leads to very high bandwidths of the drive signals, and limits the usable signal bandwidth. In a LINC type amplifier this can be solved by using negative amplitudes, but this is complicated since the drive signal then is dependent on the phase as well as on the amplitude of the desired signal. The method with negative amplitudes is not very useful in Chireix amplifiers, because the efficiency will not be as good as for positive amplitudes. This is because the compensation reactances, used to increase efficiency, will have the wrong sign and actually decrease the efficiency instead [5].

The large bandwidths also increases component requirements in order to get high linearity. Imbalances between the signal paths are also harder to control over wide bandwidths. The high power of the drive signals can also possibly cause nonlinearity in an outphasing system by leaking to the output without combining in the right way. Leakage can also be a problem in systems using linearization equipment, where the nonlinear drive signals in this way can reach sensitive nodes used for measuring or canceling distortions.

The basic idea of the present invention is to drive the amplifier linearly below a certain transition point. In an ordinary Chireix amplifier the amplitude of the drive signal is constant, and the phase difference between the amplifiers is used to generate amplitude modulation at the output. Below the transition point this leads to excessive current consumption (see Fig. 3), because the

voltage and current at each power amplifier will become more and more out of phase. The output power decreases but the transistor RF current (which can be translated to DC current) will not decrease. Thus, at some point (defined below) it is better to decrease the drive, and keep the phase difference constant, instead of continuing with outphasing action.

The described solution is applicable to both dissipative (LINC) and non-dissipative output networks, although the efficiency will not be as good with dissipative networks. Fig. 4 is a diagram similar to Fig. 2 comparing the efficiency of a conventional Chireix amplifier to the efficiency of a composite amplifier in accordance with the present invention. As can be seen from the figure, the method in accordance with the present invention increases the efficiency below the transition point T.P.

In order to generate the drive signals, it is first necessary to calculate the transition point where the amplifier should go from outphasing to linear operation. This point can easily be identified in a Chireix amplifier current plot (or a plot of amplifier efficiency) as the point where a straight line through the origin touches the current curve (see Fig. 3). It is also possible to calculate the point analytically.

The drive signals above the transition point are the same as for a conventional Chireix amplifier. Below the transition point the phase difference between the drive signals is kept constant, and the amplitude is decreased linearly toward zero in order to maximize efficiency. Fig. 5 shows a plot of the resulting transistor output currents and, for comparison, the transistor output currents for a conventional Chireix amplifier.

Fig. 6 is a block diagram of an exemplary embodiment of a composite amplifier in accordance with the present invention. As in the conventional Chireix amplifier, the input signal is forwarded to signal component separator 10. However, the same input signal is also forwarded to a block 22 that linearly amplifies the signal and provides it with a constant phase. A threshold

comparator 24 compares the output signal to a predetermined threshold (transition point). If the output signal level exceed the threshold, switches 26, 28 connect signal component separator 10 to the power amplifiers (as in the conventional Chireix amplifier). Otherwise switches 26, 28 connect the linear constant phase signals (ignoring a common phase modulation at the input) to the power amplifiers (there are two output lines from block 22, since the phases of the input signals to the power amplifiers differ in sign). As indicated by an antenna, the composite amplifier may be part of a transmitter, for example a transmitter in a base station in a cellular mobile radio communication system.

Fig. 7 is a block diagram illustrating the principles of another embodiment of a composite amplifier in accordance with the present invention. However, before this embodiment of the invention is described in detail, the general principles of this type of composite amplifier will be briefly explained.

The input signal to the composite amplifier (in order to simplify the expressions the phase-modulation is ignored, since it only adds a common phase) may be expressed as

$$s_{IN}(t) = A(t)\cos\omega t$$

In accordance with general Chireix practice, this signal is separated into the two constant-amplitude phase-modulated signals

$$\begin{cases} s_1(t) = \cos\left(\omega t + \cos^{-1} A(t)\right) \\ s_2(t) = \cos\left(\omega t - \cos^{-1} A(t)\right) \end{cases}$$

Using the trigonometric identities

$$\begin{cases}\cos(\alpha+\beta)=\cos\alpha\cos\beta-\sin\alpha\sin\beta\\ \cos(\alpha-\beta)=\cos\alpha\cos\beta+\sin\alpha\sin\beta\end{cases}$$

these signals may be expressed as

$$\begin{cases}s_1(t)=A(t)\cos\omega t-\sin\left(\cos^{-1}A(t)\right)\sin\omega t\\ s_2(t)=A(t)\cos\omega t+\sin\left(\cos^{-1}A(t)\right)\sin\omega t\end{cases}$$

Using the identity

$$\cos^{-1}\alpha=\sin^{-1}\sqrt{1-\alpha^2}$$

one obtains

$$\begin{cases}s_1(t)=A(t)\cos\omega t-\sqrt{1-A(t)^2}\sin\omega t=\mathrm{Re}\left\{\left(\underbrace{A(t)}_{L_1}+j\underbrace{\sqrt{1-A(t)^2}}_{N_1}\right)\cdot e^{j\omega t}\right\}\\ s_2(t)=A(t)\cos\omega t+\sqrt{1-A(t)^2}\sin\omega t=\mathrm{Re}\left\{\left(\underbrace{A(t)}_{L_2}-j\underbrace{\sqrt{1-A(t)^2}}_{N_2}\right)\cdot e^{j\omega t}\right\}\end{cases}$$

From these expressions linear and non-linear components may be identified as

$$\begin{cases}L_{1,2}=A(t)\\ N_{1,2}=\pm\sqrt{1-A(t)^2}\end{cases}$$

It is noted that both signals have equal linear components and equal amplitude non-linear components with opposite signs.

In some embodiments the non-linear function may be replaced by

$$\sqrt{1-(k\cdot A(t))^2}-A(t)\cdot\sqrt{1-k^2}$$

where k is a constant that is slightly smaller than the (normalized) saturation input amplitude.

In the type of composite amplifier that is illustrated in Fig. 7, the linear and non-linear components are individually adjusted (to increase efficiency as compared to an ordinary Chireix amplifier) with respect to amplitude and phase and thereafter added together again. Several adjustment methods will be discussed below.

A first method of adjusting the phases and amplitudes of the linear and non-linear drive signal components is based on emulating the behavior of the output network (which is assumed perfectly balanced) when a constant-voltage condition is imposed on the output transistors. The same voltage amplitude, usually the maximum allowed RF voltage, is used for both transistors.

The complex adjustment factors for the linear parts are obtained by calculating (for example by using a model of the amplifier) the current in each transistor output node when the transistor output node voltages are equal. This is due to the fact that the linear parts of the voltage at the transistors should be in phase with each other. If transmission lines are used in the output network, the linear parts should be out of phase in accordance with the path difference.

The complex adjustment factors for the non-linear parts are obtained by calculating (using the model) the current in each transistor output node when the transistor node voltages are of equal magnitude but of opposite sign. This is due to the fact that the non-linear parts of the voltage at the transistors should be in anti-phase with each other.

Inspection of the expression for the linear component above, reveals that it is actually a scaled version of the input signal. Thus, signal component separator 10 from the Chireix amplifier is actually not required to produce this signal. Instead only non-linear component generators are required.

Returning to Fig. 7, the linear drive signal components L_1, L_2 are produced by amplitude-phase adjusters 30, 32 directly from the input signal. Similarly, the non-linear drive signal components are generated by amplitude-phase adjusters 34, 36. If the equations above for the non-linear components N_1, N_2 were to be followed strictly, the amplitude would follow the full quarter circle indicated in blocks 34, 36 (or the corresponding curve represented by the modified equations including the factor k). However, in accordance with the present invention the amplitude dependence should be linear up to the transition point T.P., and follow the circle segment only after the transition point. Since the output signals from blocks 34, 36 are equal to N_1 and N_2 only above the transition point, they are denoted "N_1" and "N_2", respectively, in Fig. 7.

The adjusted linear and non-linear drive signal components are added in adders 38 and 40, respectively, and then forwarded to RF chains 12, 14. In an analog embodiment adders 44, 46 may, for example, be realized as hybrids. In a digital embodiment they are digital adders. As indicated by an antenna, the composite amplifier may be part of a transmitter, for example a transmitter in a base station in a cellular mobile radio communication system.

Fig. 8 is a flow chart illustrating an embodiment of the method in accordance with the present invention. Step S1 tests whether the output signal level is

above the transition point. If this is the case, step S2 drives the power amplifiers by outphased drive signals. Otherwise step S3 drives the power amplifiers by linear signals.

Fig. 9 is a diagram comparing the drive signal spectrum of the present invention to the drive signal spectrum of the prior art. Because the drive power is zero when the output amplitude is zero, there will be no sudden phase shift in the drive signal, as in the prior art, which greatly reduces the drive signal bandwidth, as shown in Fig. 9. The reduced drive signal bandwidth expansion makes it possible to increase the useful signal bandwidth. Lower drive bandwidth can also give better linearity, because balance between the two paths only has to be achieved over a smaller frequency range. Due to the linear drive at low amplitudes, the average drive power will also be lower, which will reduce the heat dissipated in the driver, and thereby total system efficiency.

In the description above it has been assumed that the power amplifiers are driven as class B amplifiers below the transition point. Although this is the presently preferred embodiment, it is also feasible to drive them as, for example class AB amplifiers. A more general criterion is that they should preferably be driven as reduced conduction angle amplifiers below the transition point.

It will be understood by those skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

REFERENCES

[1] H. Chireix, "High Power Outphasing Modulation", Proc. IRE, vol. 23, no. 11, pp. 1370-1392, Nov. 1935.

[2] K. Meinzer, "Method and System for the Linear Amplification of Signals", US Patent No. 5,012,200.

[3] R. Kohl and O. Bätz, "PAMELA - A New Methode for Linear and Efficient Power Amplification", Proc 20th EUMC, pp. 310-315, Budapest, 1990.

[4] F. H. Raab, "Efficiency of Outphasing RF Power Amplifier Systems", IEEE Trans. Communications, vol. COM-33, no. 10, pp. 1094-1099, Oct. 1985.

[5] B. Stengel and W. R. Eisenstadt, "LINC Power Amplifier Combiner Method Efficiency Optimization", IEEE Trans. Vehicular Technology, vol. 49, no. 1, pp. 229-234, Jan. 2000.

CLAIMS

1. A method of driving a composite amplifier including two power amplifiers connected to a Chireix type output network, **characterized by** driving both power amplifiers to produce power amplifier currents having an amplitude that varies linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

2. The method of claim 1, **characterized by** driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

3. The method of claim 2, **characterized by** driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

4. The method of claim 1, **characterized by** driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

5. The method of any of the preceding claims 1-4, **characterized by** driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

6. The method of claim 5, **characterized by** driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

7. The method of claim 5, **characterized by** driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

8. A composite amplifier including two power amplifiers connected to a Chireix type output network, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving both power amplifiers to produce power

amplifier currents having an amplitude that varies linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

9. The amplifier of claim 8, **characterized by** means (22, 24, 26, 28) for driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

10. The amplifier of claim 9, **characterized by** means (22) for driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

11. The amplifier of claim 8, **characterized by** means (30, 32, 34, 36, 38, 40) for driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

12. The amplifier of any of the preceding claims 8-11, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

13. The amplifier of claim 12, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

14. The amplifier of claim 12, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

15. A transmitter including a composite amplifier having two power amplifiers connected to a Chireix type output network, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving both power amplifiers to produce power amplifier currents having an amplitude that varies linearly

with input signal amplitude for output signal amplitudes below a predetermined transition point.

16. The transmitter of claim 15, **characterized by** means (22, 24, 26, 28) for driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

17. The transmitter of claim 16, **characterized by** means (22) for driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

18. The transmitter of claim 15, **characterized by** means (30, 32, 34, 36, 38, 40) for driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

19. The transmitter of any of the preceding claims 15-18, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

20. The transmitter of claim 19, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

21. The transmitter of claim 19, **characterized by** means (22, 24, 26, 28; 30, 32, 34, 36, 38, 40) for driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

U.S. CLAIMS

1. A method of driving a composite amplifier including two power amplifiers connected to a Chireix type output network, including the step of driving both power amplifiers to produce power amplifier currents having an amplitude that varies linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

2. The method of claim 1, including the step of driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

3. The method of claim 2, including the step of driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

4. The method of claim 1, including the step of driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

5. The method of any of the preceding claims 1-4, including the step of driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

6. The method of claim 5, including the step of driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

7. The method of claim 5, including the step of driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

8. A composite amplifier including two power amplifiers connected to a Chireix type output network, including means for driving both power amplifiers to produce power amplifier currents having an amplitude that varies linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

9. The amplifier of claim 8, including means for driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

10. The amplifier of claim 9, including means for driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

11. The amplifier of claim 8, including means for driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

12. The amplifier of any of the preceding claims 8-11, including means for driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

13. The amplifier of claim 12, including means for driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

14. The amplifier of claim 12, including means for driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

15. A transmitter including a composite amplifier having two power amplifiers connected to a Chireix type output network, including means for driving both power amplifiers to produce power amplifier currents having an

amplitude that varies linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

16. The transmitter of claim 15, including means for driving said power amplifiers by outphased drive signals for output signal amplitudes above said transition point.

17. The transmitter of claim 16, including means for driving said power amplifiers by drive signals having a phase that maximizes efficiency for output signal amplitudes below said transition point.

18. The transmitter of claim 15, including means for driving said power amplifiers by a combination of linear and non-linear drive signals for output signal amplitudes above said transition point.

19. The transmitter of any of the preceding claims 15-18, including means for driving said power amplifiers as reduced conduction angle amplifiers for output signal amplitudes below said transition point.

20. The transmitter of claim 19, including means for driving said power amplifiers as class B amplifiers for output signal amplitudes below said transition point.

21. The transmitter of claim 19, including means for driving said power amplifiers as class AB amplifiers for output signal amplitudes below said transition point.

ABSTRACT

A composite amplifier includes two power amplifiers (16, 18) connected to a Chireix type output network (20). Means (22, 24, 26, 28) are provided for driving the power amplifiers to produce power amplifier currents having amplitudes that vary linearly with input signal amplitude for output signal amplitudes below a predetermined transition point.

(Fig. 6)

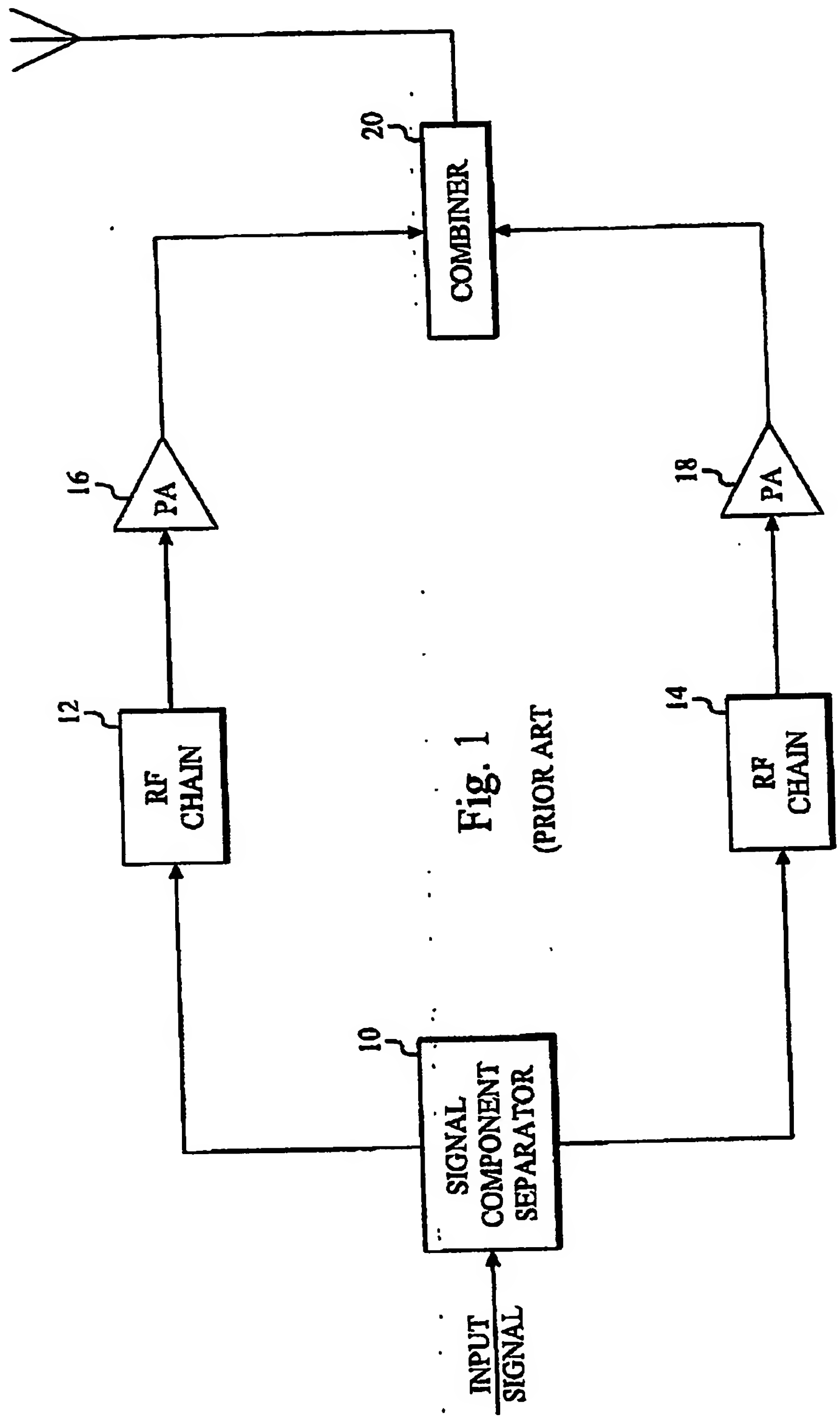


Fig. 1
(PRIOR ART

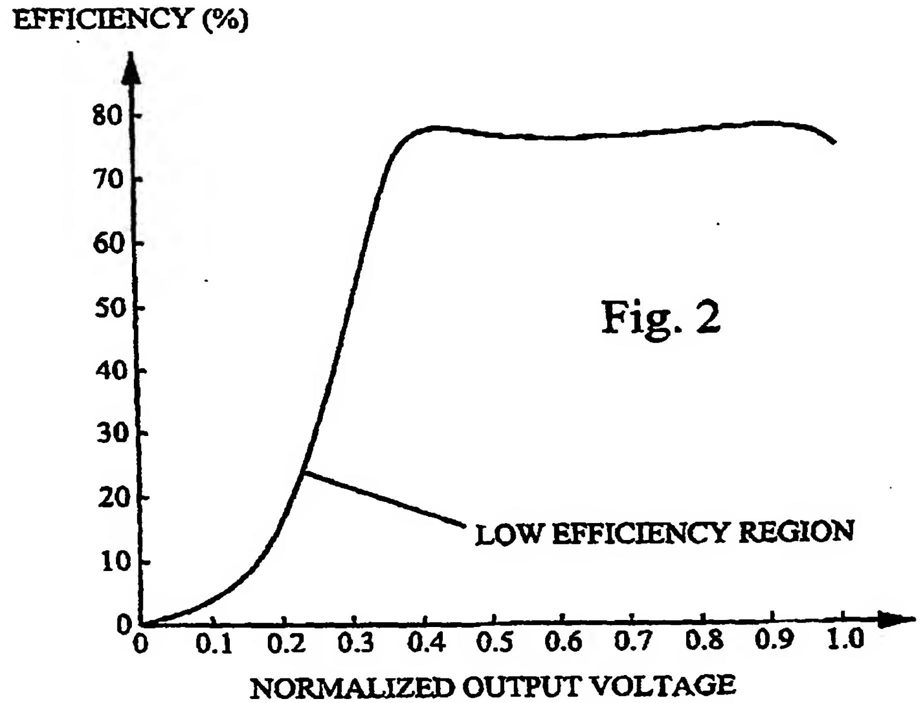
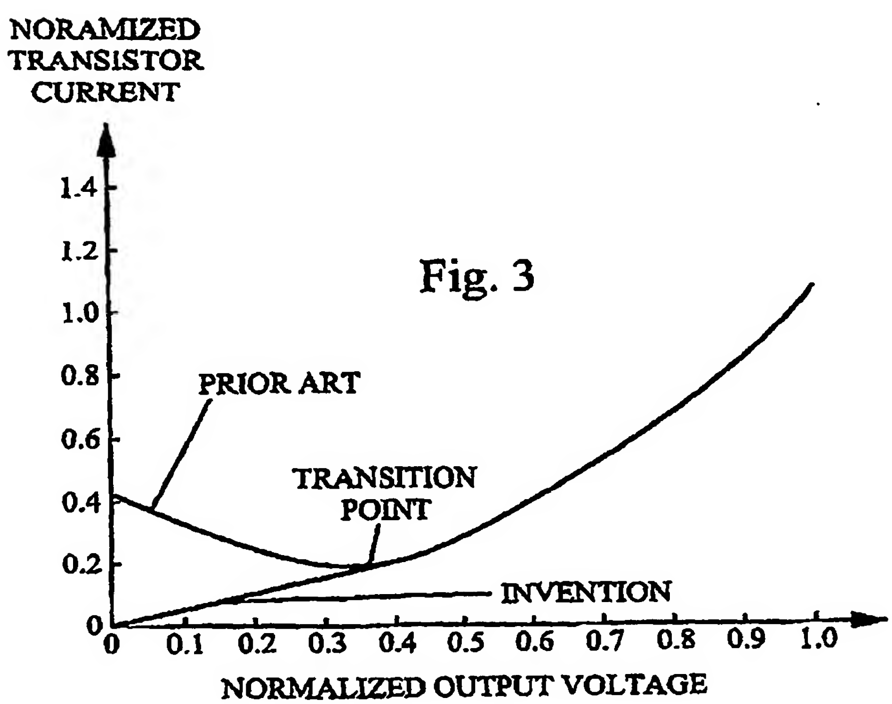

EFFICIENCY (%)
80
70
60
50
40
30
20
10
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
LOW EFFICIENCY REGION
NORMALIZED OUTPUT VOLTAGE

Fig. 2


NORAMIZED TRANSISTOR CURRENT
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1.2
1.0
0.8
0.6
0.4
0.2
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
PRIOR ART
TRANSITION POINT
INVENTION
NORMALIZED OUTPUT VOLTAGE

Fig. 3

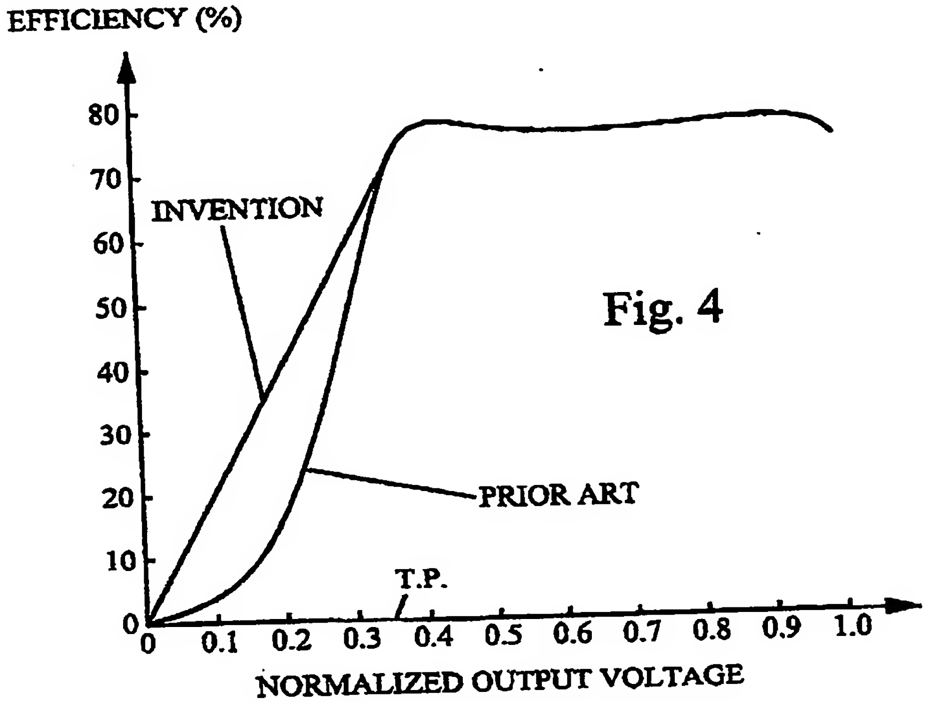
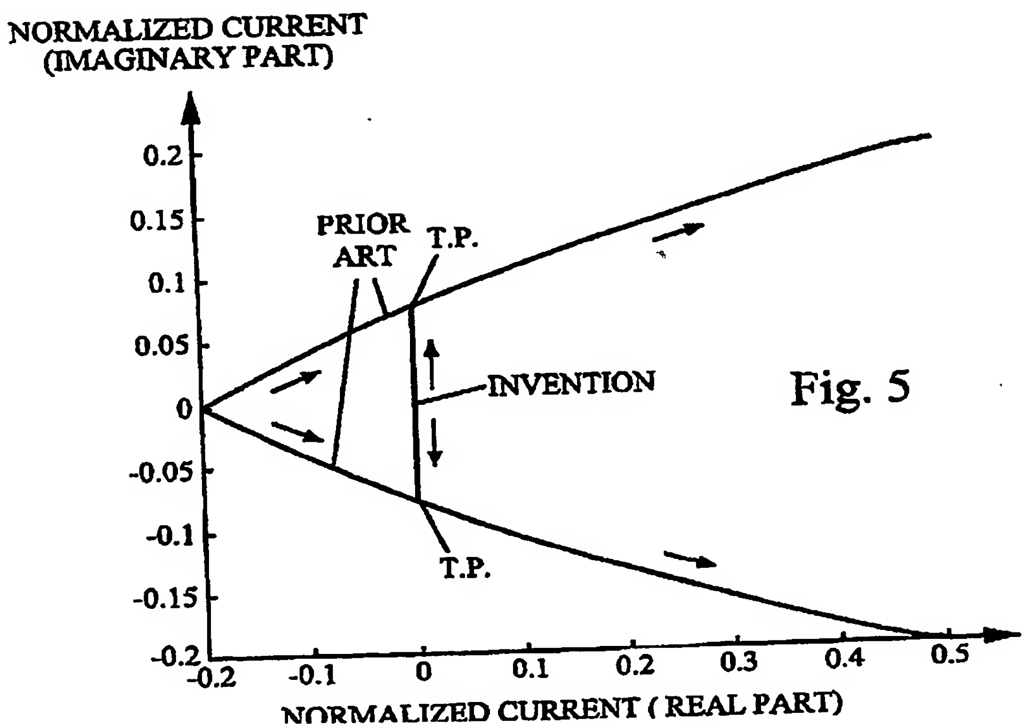

EFFICIENCY (%)
80
70
60
50
40
30
20
10
0
INVENTION
PRIOR ART
T.P.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
NORMALIZED OUTPUT VOLTAGE

Fig. 4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(IMAGINARY PART)
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0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
PRIOR
ART
T.P.
INVENTION
T.P.
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
NORMALIZED CURRENT (REAL PART)

Fig. 5

4/6

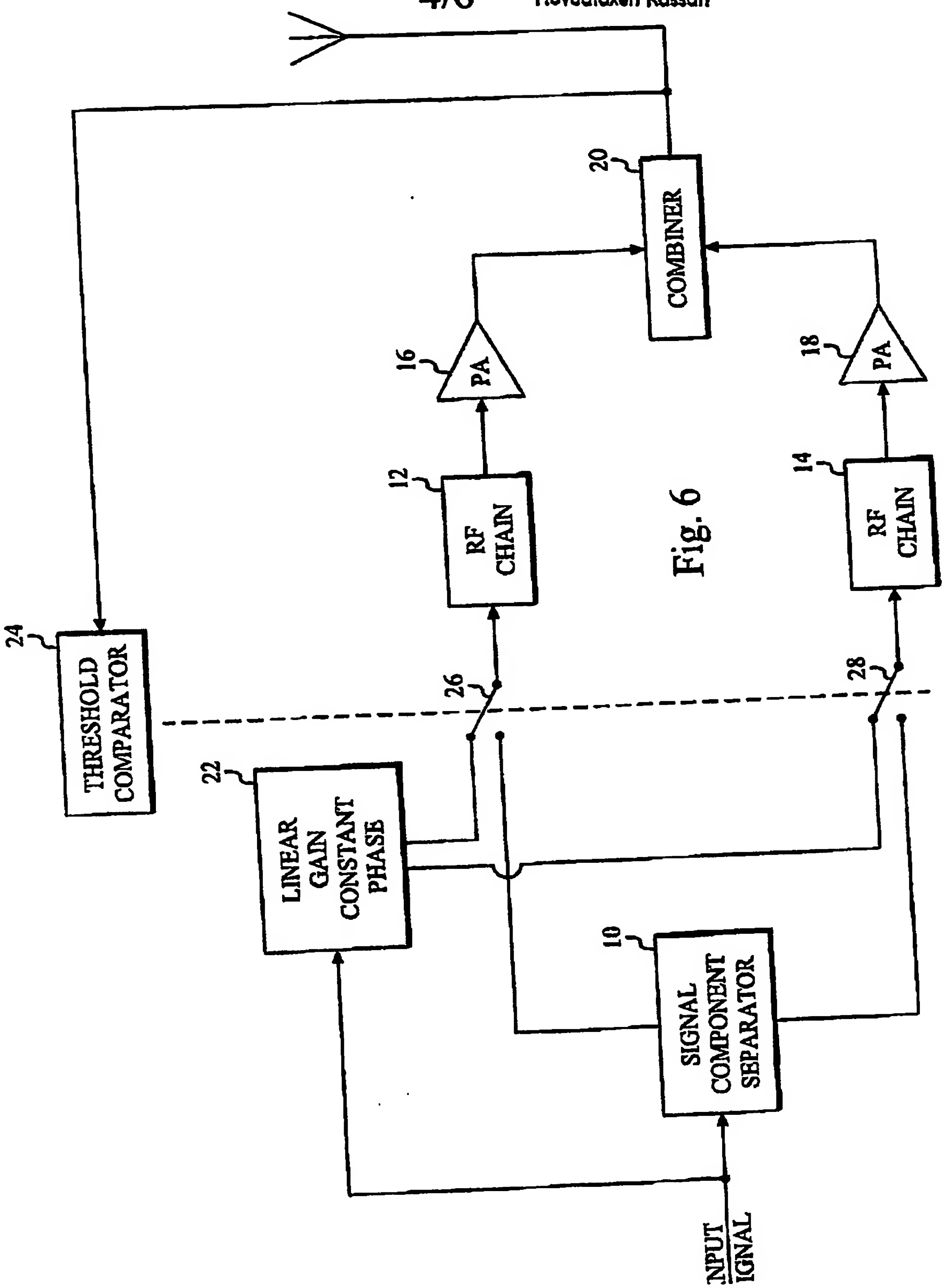
COMBINER
20
PA
16
PA
18
RF CHAIN
12
RF CHAIN
14
THRESHOLD COMPARATOR
24
26
28
LINEAR GAIN CONSTANT PHASE
22
SIGNAL COMPONENT SEPARATOR
10
NPUT
IGNAL

Fig. 6

5/6

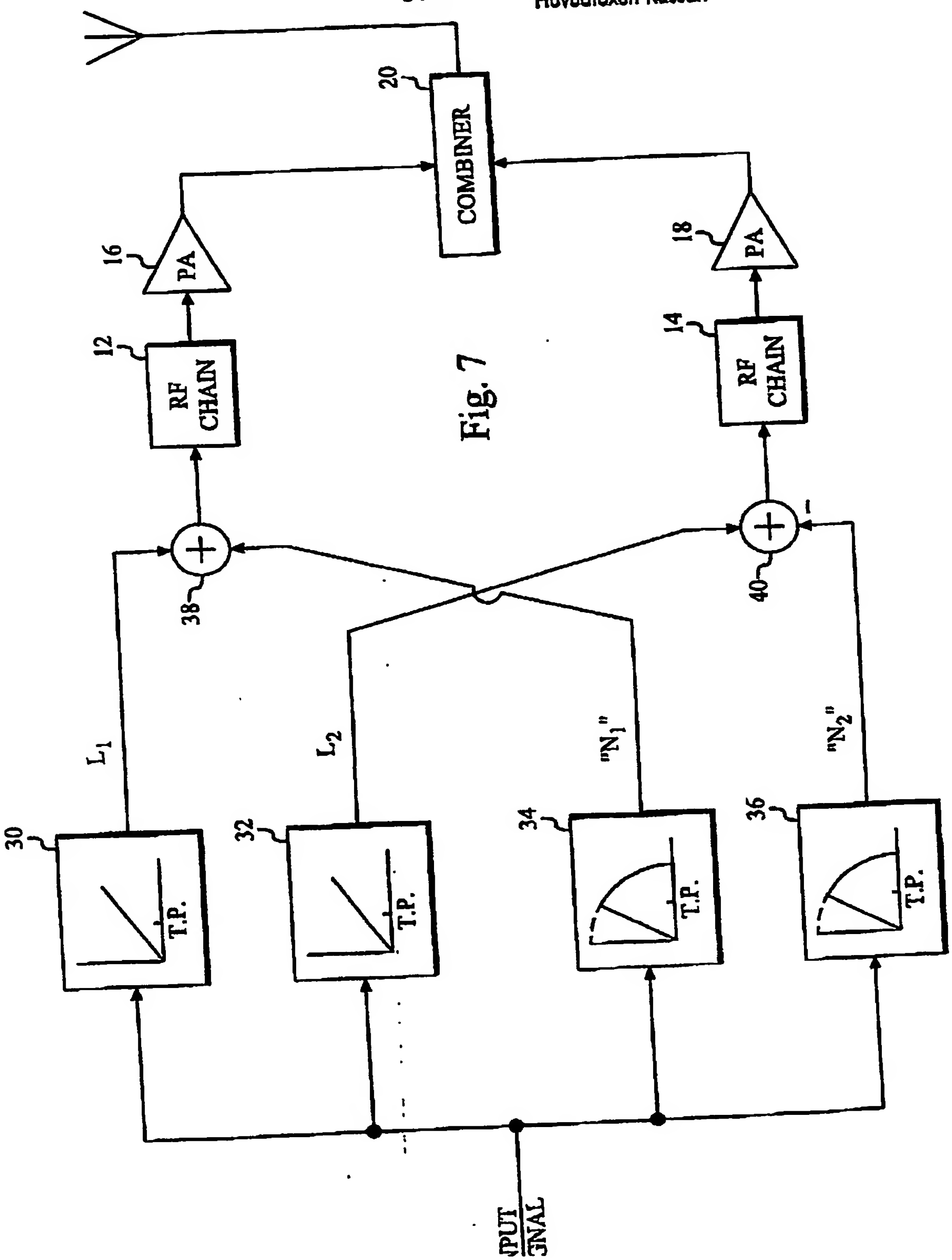
COMBINER
20
PA
16
PA
18
RF CHAIN
12
RF CHAIN
14
38
40
L_1
L_2
"N_1"
"N_2"
30
32
34
36
T.P.
T.P.
T.P.
T.P.
PUT
GNAL

Fig. 7

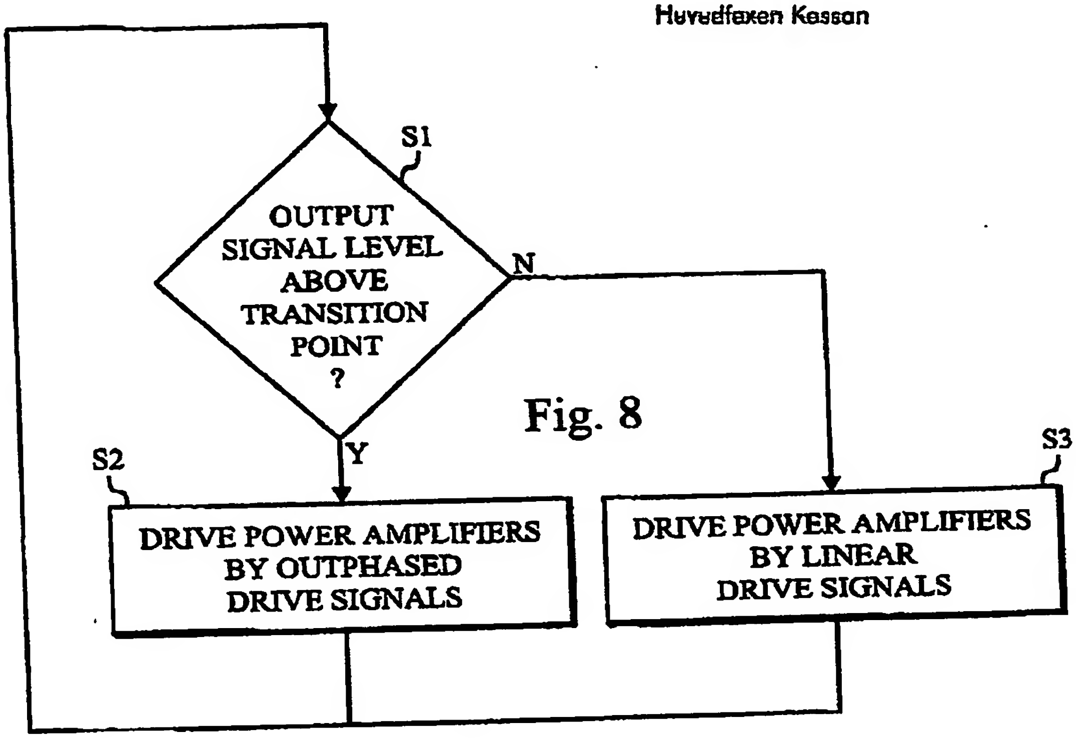
S1
OUTPUT SIGNAL LEVEL ABOVE TRANSITION POINT ?
N
Y
S2
DRIVE POWER AMPLIFIERS BY OUTPHASED DRIVE SIGNALS
S3
DRIVE POWER AMPLIFIERS BY LINEAR DRIVE SIGNALS

Fig. 8

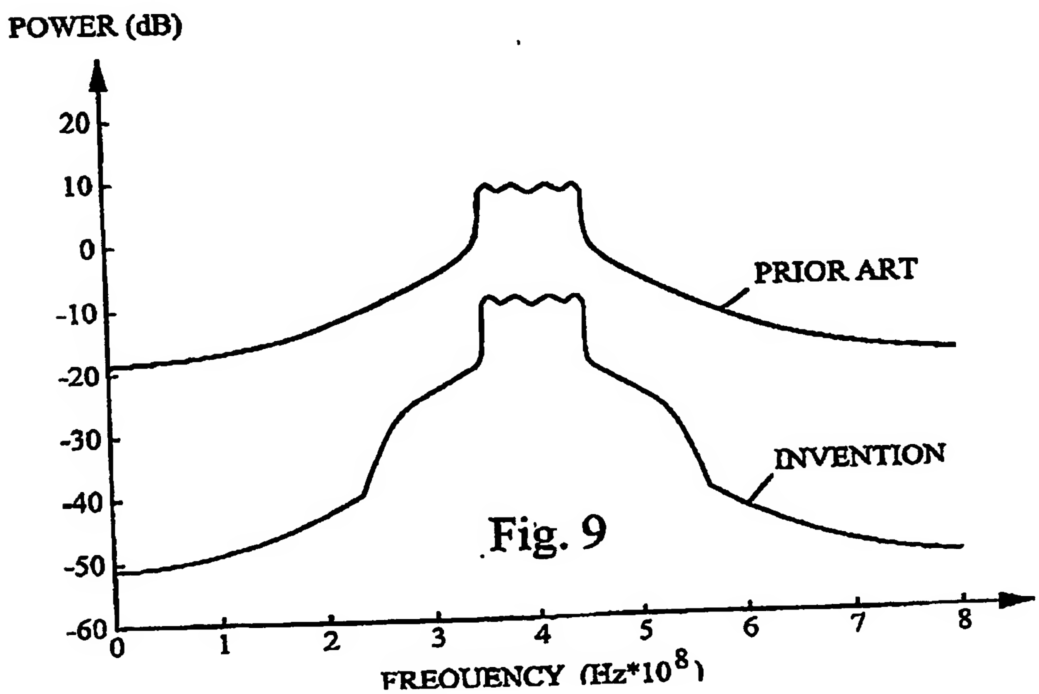
POWER (dB)
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
PRIOR ART
INVENTION
FREQUENCY (Hz*10^8)

Fig. 9